Traversability mapping for safe navigation in flooded environment

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MOTIVATION AND AIM

- **Frequency of floods:** Global warming has tremendously increased the frequency of floods across the globe.
- **Huge losses:** In 2021, floods contributed to losses of around 90 billion USD.
- **Lack of environment understanding:** The flood destroys the road network and limits the use of standard maps such as Google Maps and Open Street Maps.
- **Aim:** To develop a robotic mapping platform that provides traversability information of the destructed environment due to floods.

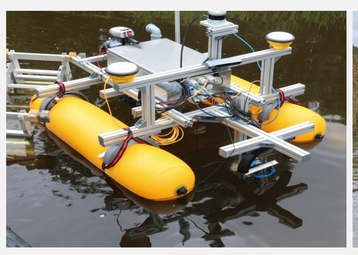
CHALLENGES

- **Randomness:** The flood brings massive random and unstructured debris, including fallen trees or destroyed bridges.
- **Highly turbid water:** The significant amount of sand particles in flood water makes it opaque and limits underwater understanding.
- **Variable depth:** The extremely shallow and variable waterbed depth threatens boat safety.
- **Scarcity of datasets:** Data collection is dangerous and often prohibited in a flooded environment, resulting in limited relevant datasets.

KEY FINDINGS

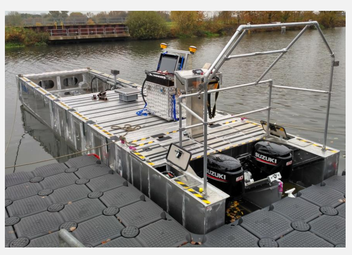
- **Water depth detection:** The sonar image's boundary between no return and seabed zone may provide accurate water depth.
- **System reconfiguration:** The parametric modular design of the system provides easy reconfiguration of the system in any other boat.
- **Multimodal information:** The underwater footprint of an obstacle may increase the detection accuracy over the surface.
- **Big dataset and realistic simulation:** In addition to a vast multi-sensor dataset from natural lakes, a realistic simulation in UNREAL Engine provides rigorous and robust testing of complex environments.

TEST PLATFORMS



Astrider

Basilisk



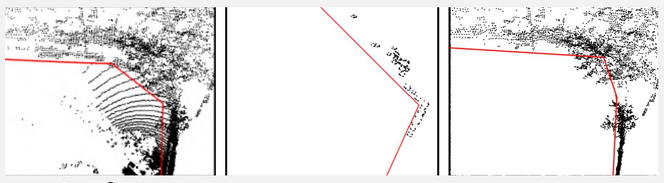
Ponton

SENSORS

Trimble GNSS, Ouster OS0-128, ZED2i Stereo Camera, Gemini 720ik

SURFACE WATER TRAVERSABILITY

LiDAR does not detect the water but detects the floating leaves, which can be safe to navigate by boat.



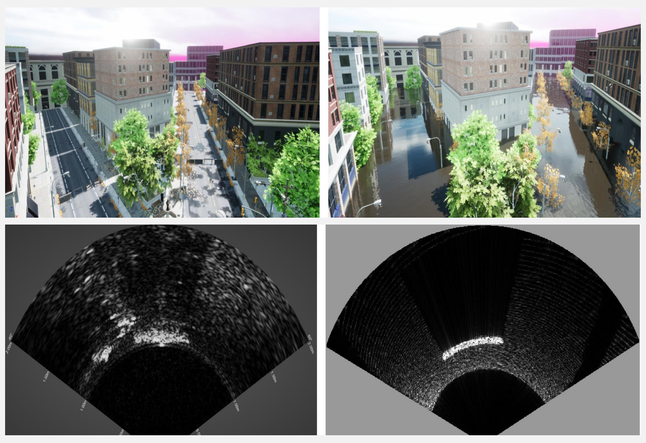
Surface Underwater Fusion

Unreal Simulation

- Due to limited flooded environment data, a realistic simulation is presented that may help in rigorous testing.
- Waves may affect the sonar data.

$$P_{ptx} = \begin{cases} P^L_{ptx}, & \text{if } h^L \geq C_h \\ max(P^L_{ptx}.\frac{h^L}{C_h}, P^S_{ptx}.d^S), & \text{else if } C_h > h^L > 0 \\ P^S_{ptx}, & \text{otherwise} \end{cases}$$

Probability of each fused point

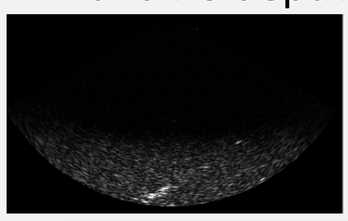


Real Sonar Simulated Sonar

UNDERWATER TRAVERSABILITY

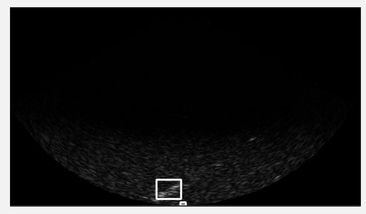
Challenges in sonar images:

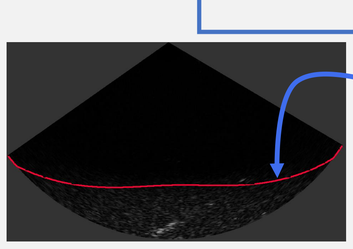
- The waterbed reverberations generate speckle noise and intensity patterns, reducing the signal-to-noise ratio.
- 2.5D Sonar image provides uncertain object dimensions and no depth information.



Raw Sonar Image

Flow Diagram

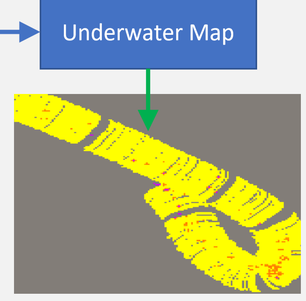




Red line defines the depth

$$P^S_{ptx} = \begin{cases} 1 - (\frac{0.4}{d_{water}}.d_{ptx}), & \text{if } d_{ptx} \leq \frac{d_{water}}{cos(90^o - vfov)} \\ 0.6, & \text{otherwise} \end{cases}$$

Probability of each sonar point



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